John B Drisko

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

MODEL STUDY OF EFFECTS OF OPERATING BIRDS POINT-NEW MADRID FLOODWAY

PAPER C

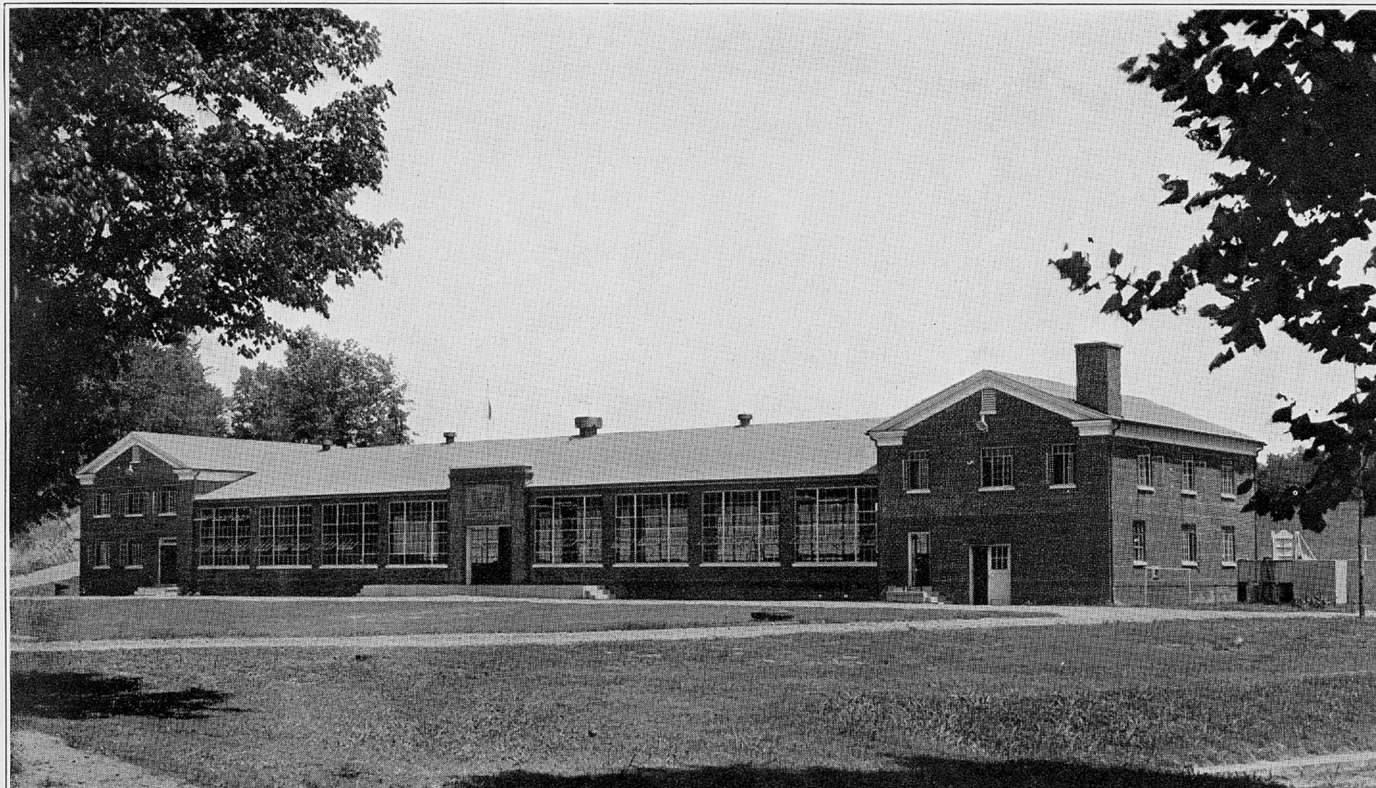
of the

U. S. Waterways Experiment Station
Vicksburg, Mississippi

For Sale by the President, Mississippi River Commission

Price 35 Cents

DEC. 1932



HOME OF THE U. S. WATERWAYS EXPERIMENT STATION--VICKSBURG, MISSISSIPPI

WAR DEPARTMENT

CORPS OF ENGINEERS, U. S. ARMY

MODEL STUDY

OF

EFFECTS OF OPERATING BIRDS POINT-NEW MADRID FLOODWAY

PAPER C

of the

U. S. Waterways Experiment Station
Vicksburg, Mississippi

M R C St Louis Mo 500 1-33

TABLE OF CONTENTS

		Page
I	Introduction	1
II	Former floods at Cairo	2
III	Purpose of the investigation	2
IV	The model	3
V	Preliminary experiments	4
VI	Effects of confined floods	5
VII	Floods under the project plan	6
VIII	Erosion and sedimentation in the floodway	9
IX	Conclusions	10
APPENDIX	A—Daily gage heights, experienced and estimated confined of floods which if confined would have exceeded 55 feet at Cairo	12
APPENDIX	B—Results of experiments, water surface elevations in river and floodway	20
APPENDIX	C—Data for model construction	27
APPENDIX	D—Hydraulic data	28
APPENDIX	E—Data for model to determine erosive properties at upper fuse plug levee	29

LIST OF TABLES

TABLE NO		PAGE
1	Tests to establish the discharge scale of the model	5
2	Area as determined from model	6
3	Comparison of experienced and confined stages	6
4	Comparison of confined to project flood stages as determined from model	7
5	Highest floods cresting below fuse plug grade subsequent to earlier crevasses in fuse plug	8
6	Water surface elevations in floodway and river as determined from model, (a) flood of 1884, (b) flood of 1927	9
7	Daily gage heights, experienced and estimated confined of floods which if confined would have exceeded 55 feet at Cairo, (a) flood of 1882, (b) flood of 1883, (c) flood of 1884, (d) flood of 1912, (e) flood of 1913, (f) flood of 1927, (g) mean flood	13
8	Results of experiments, water surface elevations in river and floodway, (a) flood of 1883, (b) flood of 1884, (c) flood 1912, (d) flood of 1913, (e) flood of 1927, (f) mean flood	21

PHOTOGRAPHS

NO		PAGE
A	Frontispiece—Home of United States Waterways Experiment Station, Vicksburg, Miss	—
B	The Model of the Birds Point-New Madrid Floodway	7

PLATES

Showing results of experiments to determine the effects of operating the Birds Point-New Madrid Floodway during a flood equivalent in magnitude to

1 The highest flood of 1883
2 The highest flood of 1884
3 The highest flood of 1912
4 The highest flood of 1913
5 The highest flood of 1927
6 The mean of the six highest floods

MODEL STUDY

OF

EFFECTS OF OPERATING BIRDS POINT-NEW MADRID FLOODWAY

I INTRODUCTION

1 The experiments on a model of the Birds Point-New Madrid floodway were conducted under authority of the President, Mississippi River Commission It was the purpose of the investigation to determine the effects of operating the floodway during floods equal in magnitude to those which have occurred since the establishment of the Cairo gage These are the floods which if confined would have produced stages in excess of 55 feet on the gage at Cairo

2 The adopted project for the control of floods in the alluvial valley of the Mississippi River provides as follows

(Doc 90, 70th Cong , 1st Session, Par 125)

> "The plan is to set back, about 5 miles, the west bank Mississippi River levee from Birds Point, opposite *Cairo, to St Johns Bayou just east of New Madrid,* 70 miles by river below Cairo, and to lower the present river bank levee by 5 feet, so that when the stage at Cairo reaches 55 feet the water will begin to flow into a wide floodway below "

The floodway area covers about 206 square miles in the state of Missouri Drawing a straight line between Cairo, Illinois, and New Madrid, Missouri, it includes approximately the area lying between this and the riverside levee from miles 3 to 70 Measured along the setback levee it is about 34 miles in length This land is generally low and during a high flood over 50 per cent of the area would normally be covered by backwater entering from St Johns Bayou

3 Construction of the floodway is provided for in the project through the building of a setback levee between Birds Point and New Madrid and the truncating of the riverside or old levee from River Miles 3 to 14 5, and 67 to 70 The lowered sections of the riverside levee, known as fuse plugs, will reserve the storage capacity of the floodway until it is most needed, viz , at the crest of the flood, and will protect the land lying within the floodway area from all floods of ordinary magnitude. The floodway will not go into operation until a stage of 55 feet at Cairo is exceeded Water may enter the floodway either by overtopping the fuse plugs or by crevassing them at one or more points

II FORMER FLOODS AT CAIRO

4 Computations by the Office of the President, Mississippi River Commission, show that since establishment of gages in 1858, only six floods, if confined within the present levee system, would have produced stages in excess of 55 feet at Cairo These were the floods of 1882, 1883, 1884, 1912, 1913, and 1927, for each of which daily gage records, together with estimated confined stages, are given in Appendix A to this report

5 The flood of 1882 crested at Cairo on February 26 at a stage of 51 87 feet Approximately one-third of the discharge came from the Mississippi River, the remaining two-thirds from the Ohio The few levees then in existence were entirely ineffective The estimated confined stage is 56 1 feet

6 The flood of 1883 crested on February 27 at 52 17 feet, under conditions similar to the flood of 1882 The estimated confined stage is 56 3 feet

7. The flood of 1884 crested on February 22 with an observed gage height of 51 79 feet During this flood the discharge from the Ohio River exceeded that of 1883, but the discharge from the Mississippi River was smaller. The estimated confined stage is 55 8 feet

8 The flood of 1912 reached a crest of 53 94 on April 6 During this flood the discharge from the Ohio River was approximately the same as in 1882, but the discharge from the Mississippi River was much greater Prior to 1912 the levee system had been extended south of Cairo for some miles and although it proved generally ineffective it tended somewhat to raise gage heights at Cairo The estimated confined stage is 58 0 feet.

9 The flood of 1913 reached a crest of 54 69 feet on April 7. The effect of levees was about as in 1912, and the estimated confined stage is 59 2 feet

10 The flood of 1927 reached an observed stage of 56 4 feet, cresting on April 20. The levee system remained intact until a short time before the crest was reached, but the effects of storage above, utilized at the crest, and of the Dorena crevasse below, were sufficient to reduce the stage by several feet at Cairo The estimated confined stage is 58 4 feet

11 A mean of the above six floods would reach 57.3 feet at Cairo if confined in the present levee system. The mean date of cresting would be March 20 and the duration of the flood (above 44 feet at Cairo) would be 29 days Assuming crevasses of the fuse plug sections to occur, the floodway would be in actual operation less than 19 days, but with no crevasses (only overtopping) this time would be considerably reduced

III PURPOSE OF THE INVESTIGATION

12 It was taken as the dual purpose of the experiment (a) to determine the effects of operation of the floodway on lands lying within it, and (b) to measure the draw-down resulting at Cairo. For each of the (six) major floods of record tests were conducted to ascertain:

(1) directions of flow in the floodway, (2) velocities of flow, (3) depths of water at all points, (4) area covered by sedimentary deposits, (5) probable locations of crevasses, and (6) water surface profiles in the main river channel between Cairo and New Madrid

IV THE MODEL

13 With more than 100 miles of river to simulate, it was decided to construct the model to a horizontal scale of 1 4800, and to apply such distortion as would be necessary to produce turbulent flow both in channels and overbank areas A vertical scale of 1 200 was selected as meeting this requirement

14 Because of the large size of the model it was located out of doors The river channel, the overbank between levees, the backwater areas and the floodway were reproduced to scale in concrete The maps from which the model was built were furnished by the Office of the President, Mississippi River Commission and by the U. S Engineer Office, Memphis, Tennessee, and are listed in Appendix C to this report To obtain detail in the model numerous cross-sections of both both river and floodway were plotted to scale and cut out of sheet metal These metal templates were set to grade and served as guides in reproducing the topography Care was taken that drainage ditches, spoil banks, levee borrow pits, etc., were correctly placed The finished model was 80 feet long and 25 feet wide

15 The water supply was obtained by gravity from the laboratory reservoir, reaching the model through a 6-inch pipe It was controlled by a valve placed in the line adjacent to the weir box The water was measured over a V-notch weir which had been calibrated at the laboratory Outflow from the model was controlled by a tailgate consisting of a variable height rectangular weir

16 Needle-point gages were used in the model and installed at points corresponding to the location of U S gages* on the river as follows

Cairo, Illinois, river mile 0 0
Columbus, Kentucky, river mile 21 6
High water gage No. 176, river mile 38 3
High water gage No. 172, river mile 60 0
New Madrid, Missouri, river mile 71 0
High water gage No 166, river mile 93 5

An adaptation of the needle-point gage was devised for obtaining water surface elevations over a number of points of known elevations, set on the model For this, a gage was mounted on an open metal stand, the bottom of which was ground to fit over the top of brass plugs used for bench marks. In operation, the gage was placed over the plug, plumbed by a level bubble mounted on the stand, and the reading secured as with the fixed type gage. In the floodway area, bench marks were set for obtaining gage readings at the following points.

*See Plate No 1

Gage No	Location
A—1	1,000 ft W of the N E cor Sec 2, T, 26 N , R 1W
A—2	At the N E cor of Sec 1, T 26 N , R 1 W
A—3	1,000 ft E of the N W cor of Sec 5, T 26 N , R 1 E
B—1	At the N E cor. of Sec 30, T 26 N , R 1 W
B—2	1,000 ft N of the S W cor of Sec 22, T 26 N , R 1 W
B—3	2,500 ft W of the N E cor of Sec 25, T 26 N , R 1 W
B—4	At the N E cor of Sec 1, T 25 N , R 2 W
B—5	2,000 ft. N of the S E cor of Sec 5, T 25 N , R 1 W
B—6	3,000 ft N of the S E cor of Sec 33, T 26 N , R 1 W
C—1	1,000 ft E of the N W cor of Sec 14, T 25 N , R 2 W
C—2	1,000 ft E of the N W cor of Sec 17, T 25 N , R 1 W
C—3	At the N E. cor of Sec 16, T 25 N , R 1 W
C—4	At the N E cor. of Sec 15, T 25 N , R 1 W
D—1	At the N E cor of Sec 3, T 24 N , R 2 W
D—2	At the N E cor of Sec 6, T 24 N , R 1 W
D—3	1,000 ft E of the N W cor of Sec 3, T 24 N , R 1 W
E—1	At the N E cor of Sec 6, T 23 N , R 2 W
E—2	At the N E cor of Sec 1, T 23 N , R 2 W
E—3	At the N.E. cor of Sec 4, T 23 N , R 1 W
F—1	At the N E cor of Sec 14, T 23 N , R. 3 W
G—1	At the N E cor of Sec 32, T 23 N , R 3 W
G—2	At the N E cor of Sec 34, T 23 N , R 3 W
G—3	At the N E cor of Sec 32, T 23 N , R 1 W

V PRELIMINARY EXPERIMENTS

17 Before conducting the experiments certain preliminary determinations and adjustments were necessary These included ascertaining from experiments the natural discharge scale of the model, and obtaining, by comparison with known flows a correct degree of roughness on the overbank areas In addition to this it was necessary in order that all of the experiments be run under exactly similar conditions to select the most probable crevasse locations and to reproduce these and their accompanying regions of scour on the concrete model

18 The natural discharge scale of the model was found by reproducing, in the model, known water surface profiles, and then plotting model discharges against model gage heights Using the Columbus, Kentucky, gage as a basis, these were plotted for less-than-bankful flows A comparison with the actual discharge curve for Columbus, based on the 1929 discharge measurements, showed the two curves to be parallel, indicating the consistency of the model scale At corresponding gage heights the discharge in cubic feet per second in nature was divided by the discharge in the model The average relationship was found to be 1 7,200,000 This figure for the "q-scale" was used in operation of the model

19 To the scale of 1.7,200,000 the 1929 flood was reproduced on the model Up to this time no provision had been made for simulating obstructions to flow on overbank areas The flow line in the model was consequently lower than the observed flow line during the 1929 flood The correct degree of roughness was obtained by placing gravel on the overbank areas, commencing at the outflow, until the water surface profile of the model had been brought to the grade of the 1929 flood

20 After making adjustments in the model, tests were conducted to verify the discharge scale All of the gage-discharge relationships, taken from the model, were found to fall within the limits of the plotted results of the 1929 measurements at Hickman, Kentucky This is revealed by a consideration of Table 1

TABLE 1

TESTS TO ESTABLISH THE DISCHARGE SCALE OF THE MODEL

Gage Height, Columbus, Ky			Model Discharge c f s	Nature[4] Discharge 1,000 c f s
Model Reading Feet[1]	Converted to Nature: Ft M G L[2]	Converted to Nature: Ft on Stand Gage[3]		
Under bankful stages				
0.916	273.2	6.7	0.0096	69
0.953	280.6	14.1	0.0240	173
0.957	281.4	14.9	0.0317	228
0.989	287.8	21.3	0.0579	416
0.997	289.4	22.9	0.0654	470
1.055	301.0	34.5	0.130	935
1.053	300.6	34.1	0.129	930
1.056	301.2	34.1	0.127	915
1.058	301.6	35.1	0.131	945
1.0595	301.9	35.4	0.130	935
Over bank stages				
1.119	313.8	47.3	0.221	1590
1.122	314.4	47.9	0.224	1610
1.122	314.4	47.9	0.227	1630
1.1285	315.7	49.2	0.228	1640
1.1145	312.9	46.4	0.225	1620
1.119	313.8	44.3	0.222	1640

[1] Gage 1.000 ft =290 ft M G L
[2] 1 foot in model = 200 ft in nature
[3] Zero of gage, 266.5 ft M G L
[4] Model discharge X 7,200,000

21 An auxiliary model of the upper fuse plug levee was built of soil taken from levee borings and from this the most likely crevasse locations were determined These will not depend entirely upon the type of soil composing the levee, but will be affected largely by hydraulic influences The soil taken by borings from the fuse plug levees was built into a model levee 0.5 feet high The sections were made similar to those existing in nature This model levee was placed on soil taken from the natural base It was packed in place and allowed to age for several weeks before testing so that the soil might regain its natural internal bond These sections were then subjected to overflow tests To check the results thus obtained, each soil sample was analyzed in the testing laboratory for relative erosivity

22 Combining both hydraulic and soil factors, it was estimated that, during the ordinary floods, two crevasses might occur in the upper fuse plug One of these crevasses was located above O'Bryan's Ridge, at about Mile 35, while the other was placed below the ridge at about Mile 44

VI EFFECTS OF CONFINED FLOODS

23 Confining floods of the past in the levee system as it existed during the 1929 flood would raise gage heights considerably over the experienced stages This would mean not only raising the river flow

line, but also the elevation of backwater. The lower part of the floodway is a natural backwater basin, and even with riverside levees maintained at sufficient height to prevent overtopping, a large portion of the area would be covered by water entering at St. John's Bayou. To determine the extent of this natural inundation from below, during each of the floods confined, the fuse plug levee was raised, and the floods were reproduced in the model. The following table gives the area covered by backwater.

TABLE 2

AREA COVERED BY BACKWATER DURING CONFINED FLOODS

As determined from model

	Backwater elevation Ft. M. G. L.	Square miles inundated	Per cent of total floodway area inundated
Flood of 1882*	300.1	106.7	51.7
1883	300.2	110.3	53.4
1884	300.0	103.1	50.0
1912	301.6	122.1	59.2
1913	302.8	127.7	61.8
1927	302.1	125.0	60.5
The Mean Flood	301.4	120.2	58.2

* Values for 1882 flood interpolated.

24. In the following table, experienced stages are taken from actual gage records of the Mississippi River Commission, and estimated confined stages are taken from the results of the model experiments.

TABLE 3

COMPARISON OF EXPERIENCED AND CONFINED STAGES

Highest Flood of	Cairo		Columbus		New Madrid	
	Exp.	Confined	Exp.	Confined	Exp.	Confined
1882	51.87	56.1*	45.1	52.4*		42.8*
1883	52.17	56.3	45.58	52.5		42.9
1884	51.79	55.9	45.37	52.2	41.50†	42.7
1912	53.94	57.9	49.00	54.0	44.11	44.5
1913	54.69	58.9	49.30	55.1	44.61	45.3
1927	56.4	58.3	51.00	54.4	43.52	44.9

* Interpolated.
† Morrison Landing, Mo., gage, 70 miles below Cairo. Zero of gage, 0.08 feet above the zero of the New Madrid gage.

VII. FLOODS UNDER THE PROJECT PLAN

25. Under the project plan, the Birds Point-New Madrid floodway will go into operation whenever a 55-foot stage is exceeded at Cairo. As the floodway goes into operation, an immediate temporary reduction (before the normal crest of the flood has been reached) will be the first effect. This temporary reduction may be followed by a rise as the storage capacity of the floodway is utilized and the flood continues to increase. As the flow becomes stabilized certain definite flow lines will be established. Assuming floods to be of sufficient duration

THE MODEL OF THE BIRDS POINT—NEW MADRID FLOODWAY
View from position of Wickliffe, Ky.
Floodway area stripped of forests to show relief.

water surface elevations should be approximately the same for floods of equal magnitude To determine flood stages in the main river, and depths, directions of flow, and velocities in the floodway area, the floods of the past were reproduced in the model as under the project plan

26 The following table of gage heights shows the comparison of floods confined in the levee system as of 1929 to the same floods when the Birds Point-New Madrid floodway is functioning

TABLE 4

COMPARISON OF CONFINED TO PROJECT FLOOD STAGES AS DETERMINED FROM MODEL

Highest Flood of	Cairo		Columbus		New Madrid	
	Confined	Under Proj Plan	Confined	Under Proj Plan	Confined	Under Proj Plan
1882	56 1	53 8	52 4*	48 7*	42 8*	42 9*
1883	56 3	53 9	52 5	48 9	42 9	43 0
1884	55 9	53 6	52 2	48 5	42 7	42 8
1911	57 9	55 9	54 0	51 0	44 5	44 4
1913	58 9	57 2	55.1	52 0	45 3	46 2
1927	58 3	56 7	54 4	51 6	44 9	45 4
Mean Flood	57 3	55 5	53 6	50 9	44 1	44 1

* Interpolated

27 Discharge through the floodway depends for a large part upon entrance conditions and upon the effectiveness of the truncated levee section acting as a fuse plug Although tests showed the discharge through the floodway to increase slightly with stage, the net draw-down in the model, measured at Cairo, remained practically the same during all of the floods, the increase in diversion during the higher floods being counteracted by the increased effect of backwater from the confined flood at New Madrid In the case of floods sufficiently high to overtop the fuse plug levee after forming two crevasses, the draw-down due to the floodway diversion was found to increase with the magnitude of the discharge

28 Following a crevasse at one point, a second crevasse may occur unless the draw-down is sufficient to prevent further overtopping of the fuse plug levee In such an instance the floodway may continue to operate at partial capacity throughout the duration of the flood With the first crevasse occurring upstream from O'Bryan's Ridge, the diversion will be less than in the case of a downstream crevasse, but the minimum lowering of main river stages along the fuse plug levee will be nearly the same The minimum reduction in stage effected at any point will, of course, control the occurrence of a second crevasse The following table shows the maximum flood (expressed in stages as confined at Cairo) which may occur after either crevasse, or both, without effecting an additional break in the fuse plug levee It may be noted that a flood reaching a confined stage of 56 7 feet or less at Cairo will cause no additional overtopping of the fuse plug levee after one crevasse has occurred

TABLE 5

HIGHEST FLOODS CRESTING BELOW FUSE PLUG GRADE SUBSEQUENT TO EARLIER CREVASSES IN FUSE PLUG

	Stage at Cairo		Water surface elevation on riverside of fuse plug levee, ft M G L				
	Confined flood	Floodway functioning	Levee Mile				
			35	37	39	41	43
Crevasse at Mile 35	56.7	56.0	322.7	322.7	321.9	321.2	320.6
Crevasse at Mile 44	56.8	56.1	323.1	322.5	321.5	320.4	319.4
Both crevasses	58.9	57.2	323.0	321.8	321.0	320.4	320.0
Elev of crown of fuse plug levee			323.1	322.7	321.9	321.2	320.6

29 The head lost in flowage between the river and the floodway will materially reduce water surface elevations in the floodway area under elevations in the river directly opposite This is because the water flowing through the crevasses will attain high local velocities, and will assume a steep gradient until flow becomes distributed At the crest of the 1913 flood the head lost through the upper crevasse would have been about 2 feet; through the lower crevasse about 4 feet That is the water surface elevations in the floodway except at the crevasses would have been about that much lower than in the river at points directly opposite Not all of the floodway would have been inundated during any of these former floods even though crevasses had occurred both above and below O'Bryan's Ridge Portions of that ridge would have been above the crests of the highest floods of record. For floods within the magnitudes of the floods of 1882, 1883, or 1884 a large section in the upper part of the floodway would remain entirely dry if the fuse plug should crevasse below O'Bryan's Ridge only For each of the experienced floods, water surface contours have been plotted from the results of the model experiments Except for the 1884 flood these show water surface elevations after both crevasses have occurred For the 1884 flood, water surface elevations are shown for three conditions, viz , a crevasse above O'Bryan's Ridge, a crevasse below O'Bryan's Ridge, and both crevasses The flood of 1882 was not reproduced in the model since it was almost identical in magnitude to the flood of 1883 The results of these experiments are shown in Plates Nos 1 to 6 In the following tables are contained the water surface elevations along both the floodway side and the river side of the front line levee The table for the flood of 1884 serves to illustrate the condition where the levee may crevasse either above or below O'Bryan's Ridge, or at both places The second table, for the flood of 1927, shows water surface elevations during one of the higher floods when both crevasses will occur

TABLE 6

WATER SURFACE ELEVATIONS IN FLOODWAY AND RIVER AS DETERMINED FROM MODEL

Flood of 1884

Feet above Mean Gulf Level

Levee Mile	Crevasse at mile 35		Crevasse at mile 44		Both Crevasses	
	River	Floodway	River	Floodway	River	Floodway
33	324.0	320.5	324.4	dry	323.2	319.5
39	320.1	319.3	319.6	dry	318.0	318.2
45	319.2	312.5	318.4	315.0	317.4	313.5
50	317.8	306.5	316.4	309.0	315.0	309.5
65	311.7	303.3	310.5	306.3	308.7	307.0

Flood of 1927

Feet above Mean Gulf Level

Levee Mile	*Main River*	*Floodway*
33	326.2	320.8
39	320.4	319.3
45	319.8	315.5
50	318.0	311.5
65	312.1	310.2

30. Outside of the immediate vicinity of crevasses high velocities will not occur in the floodway. In the model the tendency of flow was to spread out over the entire area and become uniformly distributed within a short distance of the fuse plug. Velocities as high as 8.5 feet per second were observed in the crevasse area. Over the low ground through O'Bryan's Ridge, a maximum of about 6 feet per second was observed, while velocities across the ridge were less than 4 feet per second. South of the railroad, in sections 5, 9, and 15, velocities ranged between 3 and 4 feet per second. Still further south, they were much lower. In the accompanying plates, solid flow-arrows indicate velocities in excess of 2 feet per second, broken arrows, less than 2 feet per second.

VIII. EROSION AND SEDIMENTATION IN THE FLOODWAY

31. *Sedimentary deposits in the floodway may be generally* divided into two classes. To one belong the lighter silts and the clays carried in mechanical suspension, to the other the heavier river sands usually moved along the bottom by saltation. Deposits of silts and clays will be beneficial to the soil. They become mixed in deposition with small amounts of sand and provide one of the best soils for agricultural purposes. Silt may be held in suspension even at fairly low velocities (less than 3 feet per second) and the finer silt and clay may be transported at velocities still less. The river sands may form damaging deposits, these deposits usually occurring in ridges resembling a river sand bar. The movement of sand is slow except at exceedingly high water velocities and is confined to the strata near the bottom. Its progression is nearly always in waves, or dunes. To represent these two classes of materials in the model very fine silt was used for the former

and very fine sand for the latter While the areas subject to scour or deposit depended upon the local conditions, they were defined roughly Experiments to determine these effects were conducted only on the mean flood, the same results being equally applicable to the other floods, qualitatively speaking

32 Heavy material, removed from the vicinity of crevasses, and river sand brought in by the high velocities in the immediate crevasse areas, were shown by the tests to be deposited in a large ring formation extending one-half to two miles from the crevasses Erosion of finer soils appeared probable within this area

33 The velocities and depths across O'Bryan's Ridge indicated that some erosion may occur there. This will be governed largely by the soil covering, cultivation, types of soils etc Other things being equal, the clay soils will be the most resistant, the sands and silts, the least Harmful erosion will not occur outside of this locality and the crevasse areas mentioned above

34 Deposits of fine sediment will occur generally over the entire floodway with the exception of O'Bryan's Ridge and the crevasse areas These deposits consisting of the finer silts and the clays will be light and will be of material benefit to the soil They will be heaviest in the upper part of the floodway above O'Bryan's Ridge and in the wide section west of Belmont Outside of the crevasse areas, it is unlikely that harmful deposits will occur

35 The model indicated that the drainage system will not be effected seriously outside of the crevasse area Across O'Bryan's Ridge the ditches paralleling the direction of flow will be enlarged somewhat In other sections of the floodway it may be taken as a general rule that parallel flow may result in slight enlargement, cross-flow in slight silting The silting will vary in amount with the attendant velocities and will decrease toward the lower part of the floodway

IX CONCLUSIONS

36 The following general conclusions concerning the functioning of the floodway follow as a result of the model investigation

(a) With the flood stage at Cairo limited to 59 0 feet, and under the conditions as fixed in the model, the maximum flood possible is about 2,350,000 cubic feet per second Discharge through the floodway will be approximately 400,000 cubic feet per second at that stage

(b) The set-back levee is built with ample free board above the highest flood which is contemplated under the project plan

(c) Except for a belt of land extending along the inside of the upper fuse plug, the land lying in the floodway area will suffer no permanent damage from the periods of inundation Within a half-mile below a crevasse in the fuse plug almost any kind of damage is likely to occur, within three miles below a crevasse in the fuse plug damaging sand deposits may occur These conditions are similar to those occurring as the result of any crevasse Except as noted above the deposits will be beneficial There is a probability of erosion on O'Bryan's Ridge The drainage system will be only slightly affected outside the three-mile arc mentioned above

(d) Along the lower extremity of the set-back levee, near New Madrid, the greater part of outflow from the floodway is forced through the quarter-mile-wide opening between the riverside and the set-back levees. There will of course be flow over the truncated levee of the lower fuse plug which extends a length of 5 miles from Conran Dike to St John Bayou, but this flow will be limited to a small percentage of the total. The actual depth of water over the fuse plug has been found to vary with floods considered in this study from a maximum of 5 feet to a minimum of 2 feet There will be no decided overfall, consequently no free weir action and probably no crevasse Because of this, outflow is forced at high velocities down the levee borrow pit, which is utilized as a drainage ditch, and at the end of the set-back levee considerable erosion is possible Since removal of the end of this levee would allow currents to impinge directly on the levee protecting New Madrid on the east it is recommended that, during the first period of operation a close inspection be maintained over this section and if any tendencies to erode become manifest the end of the set-back levee be protected. From a hydraulic view point it will be inadvisable to close the existing breeches in the lower fuse plug which, in status quo, will be of value in dispersing the flow

HERBERT D VOGEL,
1st Lieut , C E ,
Director, U S Waterways Experiment Station

Vicksburg, Mississippi
December, 1932

APPENDIX A

DAILY GAGE HEIGHTS, EXPERIENCED AND ESTIMATED CONFINED, OF FLOODS WHICH, IF CONFINED, WOULD HAVE EXCEEDED 55 FEET AT CAIRO, ILLINOIS

37 It is estimated by the President's Office, Mississippi River Commission[1], that if floods of the past had been confined in the levee system there would have been six to exceed 55 feet at Cairo since 1858. The record for the Cairo gage has been continuous since that date with the exception of the years 1859, 1863 and 1869 Those missing are known to have been of moderate rainfall in the Mississippi drainage area The theoretically computed frequency[2] of floods sufficient in magnitude to put the floodway into operation is once in 12½ years during this 74-year period

38 For each of the six floods which would, if confined, have exceeded 55 feet at Cairo, the experienced and the estimated confined stages are given in the following tables Considering the operation of the floodway, and the damage resulting to the land within its area the duration of the flood is as important as the stage Daily gage heights are therefore given from the time the flood exceeds bankful stages until it has returned to within banks These data have been taken from "Hydrographs and Supporting Data for Various Floods at Cairo, Ill [3]" complied by the U. S. Engineer Office, Memphis, Tennessee

---

[1] Estimated Stages at Cairo Required for Confined Flood, memorandum for the President, Mississippi River Commission, by F J Thomas, Principal Engineer, dated April 25, 1930 (3238/144/1)

[2] Flood Frequency Curve Cairo, Ill , 73 year Period 1858 1930, U S Engineer Office, Memphis, Tenn (Se 2093)

[3] Tables and Hydrographs dated April and May, 1931 (Ser 2254 and 2255)

TABLE NO 7.

DAILY GAGE HEIGHTS, EXPERIENCED AND ESTIMATED CONFINED, OF FLOODS WHICH IF CONFINED WOULD HAVE EXCEEDED 55 FEET AT CAIRO

TABLE NO 7a

THE HIGHEST FLOOD OF 1882

Gage Height at Cairo

Date		Stage		Date		Stage	
		Observed	Est Conf			Observed	Est Conf
Jan	27	47.40	49 2	Mar	1	51 00	54 5
	28	47 50	49 3		2	50 62	53 9
	29	47 54	49 4		3	50 30	53 4
	30	47 60	49 5		4	49 95	53 0
	31	47 64	49 5		5	49 52	52 25
Feb	1	47 64	49 5		6	49 02	51 5
	2	47 72	40 6		7	48 54	50 8
	3	47.70	49 6		8	48 12	50 15
	4	47 66	49 5		9	47 87	49 85
	5	47 50	49.3		10	47 70	49 6
	6	47 30	49 0		11	47 50	49 3
	7	47 00	48 5		12	47 55	49 4
	8	46 80	48 2		13	47 82	49 7
	9	46 48	47 8		14	47 97	50.0
	10	46 00	47.0		15	47 97	50 0
	11	45 50	46 3		16	47 78	49 65
	12	44 94	45 4		17	47 50	49 25
	13	44 58	44 8		18	47 10	48 6
	14	44.40	44 6		19	46 60	47.8
	15	44 23	44 3		20	46 02	47 0
	16	44 20	44 2		21	45 33	46 0
	17	45 00	45 1		22	44 38	44 6
	18	45 38	45 8		23	43 36	
	19	45 84	46 0		24	42 44	
	20	46 10	46 5		25	41 80	
	21	47 40	49 0		26	41 47	
	22	49 52	52 2		27	41 38	
	23	50 80	54 3		28	41 32	
	25	51 56	55 6				
	25	51 83	56 0				
	26	51 87	56 1				
	27	51 68	55 9				
	28	51 40	55 3				

TABLE NO 7b

THE HIGHEST FLOOD OF 1883

Gage Height at Cairo

Date		Stage		Date		Stage	
		Observed	Est Conf			Observed	Est Conf
Jan	28	28 35		Mar	1	51 83	55 5
	29	29 80			2	51 40	54 8
	30	30 73			3	50 80	53 9
	31	30 35			4	50.10	53 0
Feb.	1	30 00			5	49 20	51 4
	2	29 74			6	48 15	50 0
	3	29 50			7	46 95	48 4
	4	29 68			8	45 60	46 2
	5	29.76			9	44 28	
	6	28 93			10	42.95	
	7	29 20			11	41 60	
	8	31 18			12	40 00	
	9	32 98			13	38 28	
	10	34 40			14	36.60	
	11	36 10			15	34 90	
	12	38 20			16	33 28	
	13	39 75			17	31 82	
	14	41 25			18	30 55	
	15	43 32			19	29 12	
	16	45 30	45 9		20	27 84	
	17	47 05	48 50		21	26 64	
	18	48 95	51 25		22	25 82	
	19	50 50	53 3		23	25.20	
	20	51 44	54 8		24	24.74	
	21	51 79	55 5		25	24 40	
	22	51 79	55 5		26	24 28	
	23	51.79	55 5		27	24 40	
	24	51 26	55 9		27	24 58	
	25	52 04	55 9		29	24 80	
	26	52 13	56 05				
	27	52 17	56 3				
	28	52 08	56 05				

TABLE NO 7c

THE HIGHEST FLOOD OF 1884

Gage Height at Cairo

Date	Stage Observed	Stage Est Conf	Date	Stage Observed	Stage Est. Conf
Jan 23	28 14		Mar 1	49 50	52.3
24	27 92		2	48 65	51 2
25	27 40		3	47 72	49 6
26	26 83		4	46 55	48 0
27	26 57		5	45 15	45 8
28	26 28		6	43 50	
29	25 70		7	41 65	
30	24.97		8	39 75	
31	25.65		9	38 10	
Feb 1	25 60		10	36 80	
2	26.05		11	36 10	
3	28 73		12	36 38	
4	31 78		13	37 28	
5	34 20		14	38 63	
6	36 95		15	39 90	
7	40 28		16	41.05	
8	42 31		17	42 10	
9	43 77		18	43 08	
10	44 89	45 4	19	43 96	
11	45 83	46 7	20	44 85	45 2
12	16 62	47 9	21	45 85	46 8
13	47 44	49.1	22	46 60	47 9
14	48 22	50 3	23	47 15	48 8
15	49.00	51.5			
16	49 70	52.5			
17	50 30	53 35			
18	50 75	54 2			
19	51.15	54 8			
20	51 46	55 3			
21	51.75	55 7			
22	51 79	55 8			
23	51 79	55.8			
24	51.79	55 8			
25	51.71	55 7			
26	51 50	55 35			
27	51.19	54.8			
28	50.70	54 1			
29	50 15	53 3			

TABLE NO 7d

THE HIGHEST FLOOD OF 1912

Gage Height at Cairo

Date	Stage		Date	Stage	
	Observed	Est Cont		Observed	Est Conf
Mar 8	40 1		Apr 8	53 9	57 9
9	39 3		9	53 8	57 7
10	38.1		10	53 7	57 5
11	87 1		11	53 6	57 2
13	36 3		12	53 5	56 9
13	35 4		13	53 2	56 3
14	34 6		14	52 9	55 7
15	34 3		15	52 4	54 8
16	35 0		16	51 8	53 8
17	36 3		17	51 0	52 6
18	38.4		18	50 0	51 1
19	40 6		19	49 0	49 7
20	42 5		20	47 9	48 3
21	44 2		21	47 0	47 1
22	45 4		22	45 9	
23	46.4	46 5	23	44 7	
24	47 5	47 7	24	43 4	
25	48 4	48 7	25	42 3	
26	49 2	49 6	26	41 5	
27	49 8	50 25	27	41 4	
28	50 4	51 0	28	42.2	
29	51 0	51 7	29	44.0	
30	51 6	52 5	30	45 5	
31	52 2	53 5	May 1	46 9	47.7
Apr 1	52 7	54 5	2	48 1	49 5
2	53 5	55 7	3	48 9	50 7
3	53 7	56 7	4	49 2	51 1
4	53 8	57 4	5	49.2	51 1
5	53 7	57 7	6	49.1	50 9
6	53 94	58 0	7	48 8	50 5
7	53 94	58 0			

TABLE NO 7e

THE HIGHEST FLOOD OF 1913

Gage Height at Cairo

Date		Stage		Date		Stage	
		Observed	Est Conf			Observed	Est. Conf
Mar	8	31 9		Apr	8	54.6	59.1
	9	30 9			9	54 5	58 9
	10	29 4			10	54 5	58 7
	11	27 7			11	54 3	58 3
	12	26 1			12	54 0	57 7
	13	24 9			13	53 5	56 9
	14	24 5			14	52 9	55 9
	15	25 0			15	52.2	54.7
	16	26 8			16	51 4	53 4
	17	29 5			17	50 6	52 0
	18	31.9			18	49 6	50.5
	19	33 8			19	48 6	49 1
	20	35.2			20	47 4	47.6
	21	36.9			21	46 3	46 4
	22	39 0			22	45 0	
	23	39 8			23	43 6	
	24	40 3			24	42 1	
	25	41 0			25	40 4	
	26	43 6			26	38 4	
	27	45 5			27	36 1	
	28	47 5	47 6		28	33 7	
	29	49 1	49 3		29	37 4	
	30	50 7	51 0		30	29 5	
	31	52 0	52 4	May	1	28.0	
Apr	1	53 3	53 8		2	26 7	
	2	54 0	55 0		3	25 8	
	3	54.5	56 4		4	25 0	
	4	54 6	57 5		5	24 3	
	5	54 6	58 4		6	23 7	
	6	54 6	58 9		7	23 1	
	7	54.69	59 2				

TABLE NO 7f

THE HIGHFST FIOOD OF 1927

Gage Height at Cairo

Date		Stage		Date		Stage	
		Observed	Est Conf.			Obsrrved	Est Conf
Mar	21	49 6		May	1	49 8	50 2
	22	51 2			2	48.9	49 1
	23	52 2			3	47.7	47 8
	24	52 7			4	46 4	
	25	52 8			5	44 9	
	26	52 4			6	43 9	
	27	51 8			7	42 9	
	28	51 1			8	42 1	
	29	50.2			9	41 8	
	30	49 6			10	42 3	
	31	49 1			11	43 1	
Apr	1	49 4			12	43 6	
	2	50.0			13	43.9	
	3	50 8			14	43 9	
	4	51 6			15	43 4	
	5	52 3			16	42 2	
	6	52 8			17	40 9	
	7	53 1			18	39 9	
	8	53.1			19	39 0	
	9	53 0			20	38 1	
	10	52 5					
	11	52 3					
	12	52 3					
	13	52 7					
	14	53 7					
	15	54.6	54 75				
	16	55 6	56 5				
	17	56.1	57 7				
	18	56 3	58 2				
	19	56.3	58 4				
	20	56.4	58 5				
	21	56 1	58 2				
	22	55 7	57 7				
	23	55 3	57 1				
	24	54 8	56 4				
	25	54 0	55 15				
	26	53 2	54 1				
	27	52.4	53 2				
	28	51 7	52 35				
	29	51 0	51 55				
	30	50 4	50 9				

TABLE NO 7g

MEAN OF THE HIGHEST FLOODS OF 1882, 1883, 1884, 1912, 1913 AND 1927

Gage Height at Cairo

Date	Stage		Date	Stage	
	Observed	Est Conf		Observed	Est Conf
Feb 18	37.6	37 9	Mar. 21	53 4	57 2
19	37 8	38 1	22	53 2	56 8
20	37 6	37.9	23	52.9	56.4
21	37 05	37.4	24	52 6	55 8
22	36 6	36 9	25	52 2	55 2
23	36 0	36 35	26	51.6	54 3
24	35 6	35 95	27	51.0	53 4
25	35 5	35 8	28	50 4	52 3
26	35 8	36 15	29	49 5	51.2
27	36 2	36.5	30	48 7	49 9
28	37 5	37 8	31	47 8	48 8
Mar 1	38 45	38 7	Apr 1	46 8	47 5
2	39 9	40.1	2	45 7	46 1
3	41.2	41 4	3	44 5	44 9
4	42 5	42 7	4	43.3	43 6
5	43 75	43 9	5	42 2	42 5
6	44 6	44 1	6	41 1	41 4
7	45 35	45 4	7	40 1	40 4
8	46.4	46 6	8	39 4	39 65
9	47 3	47 6	9	38 9	39 1
10	48 05	48 6	10	38 7	39 9
11	9 0	49 8	11	38 6	38 8
12	49 8	50 85	12	38 5	38 6
13	50.5	51 8	13	38 4	38 6
14	51 2	52 75	14	38 2	38 5
15	51.9	53 9	15	37 95	38 25
16	52.7	55.25	16	37 7	38 05
17	53 1	56 3	17	37 5	38 0
18	53 3	56 9	18	37 4	37.9
19	53 4	57 2	19	37 2	37 8
20	53 5	57 3			

APPENDIX B

WATER SURFACE ELEVATIONS IN RIVER AND FLOODWAY AS DETERMINED FROM MODEL TESTS

39 In the accompanying tables are given the results of experiments to determine water surface elevations during floods exceeding 55 feet at Cairo Gage readings were secured at a sufficient number of points to enable flow lines to be established for both river and floodway The figures given represent the average of a number of runs for each flood The only flood exceeding 55 feet which was not included in the experiments was the flood of 1882, which is so nearly identical to the flood of 1883 that figures for the two may be used interchangeably. The mean flood is a weighted mean of the floods of 1882, 1883, 1884, 1912, 1913 and 1927 The location of gages on the model is given in Section 24

TABLES NO. 8

RESULTS OF EXPERIMENTS, WATER SURFACE ELEVATIONS IN RIVER AND FLOODWAY

TABLE NO. 8a

HIGHEST FLOOD OF 1883

Gage	River Mile	Water Surface elevations, feet above M. G. L.	
		Confined flood	B. P.-N. M. Floodway functioning
		River	
Cairo	0	326.7	324.3
Columbus	21.6	319.0	315.4
H. W. 176	39.4	312.7	309.2
H. W. 172	60.0	305.0	303.2
New Madrid	71.0	298.9	299.0
		Floodway	
A_1		dry	318.4
A_2		dry	318.8
A_3		dry	318.6
B_1		dry	dry
B_2		dry	317.4
B_3		dry	317.0
B_4		dry	310.4
B_5		dry	312.1
B_6		dry	313.7
C_1		dry	310.0
C_2		dry	310.3
C_3		dry	310.4
C_4		dry	313.1
D_1		300.4	308.7
D_2		dry	308.4
D_3		dry	310.0
E_1		300.4	306.8
E_2		300.0	307.3
E_3		300.0	307.4
F_1		300.0	305.4
G_1		300.0	303.4
G_2		300.4	304.3
G_3			307.6

TABLE NO 8b

HIGHEST FLOOD OF 1884

Gage	River Mile	Water Surface elevations, feet above M G L			
		Confined flood	B P -N M. Floodway Functioning		
			Crevasses at Levee M 44	Crevasse at Levee M 35	Both Crevasses
River					
Cairo	0	326 3	325 9	325 6	324 0
Columbus	21 6	318 7	316 4	317 9	315 0
H W 176	38 3	312 2	310 5	311 7	308 7
H W 172	60 0	304 5	303 7	304 3	302 8
New Madrid	71 0	298.7	259 8	299 3	298 4
Floodway					
A_1		dry	dry	319 8	318 3
A_2		dry	dry	320 3	318 6
A_3		dry	dry	320 8	318.4
B_1		dry	dry	dry	dry
B_2		dry	dry	318 6	317 1
B_3		dry		319 1	316 8
B_4		dry			
B_5		dry	312.4	310 6	313 1
B_6		dry	312 2	312 3	313 4
C_1		dry			
C_2		dry	310 1	308 2	310 1
C_3		dry	310.3	308 0	310 3
C_4		dry	314 5	311 0	313 3
D_1		300 6	307 7	304.4	308 3
D_2		dry	307 8	305 0	308.0
D_3		dry			
E_1		300 0	305.9	305 5	306.4
E_2		300 0	306 3	303 0	307 0
E_3		300 0	306 5	303 1	307 2
F_1		300 0	305 1	302 1	305 0
G_1		299 8	303 2	301 2	303 1
G_2		300 0	304 1	301 8	304 0
G_3			306 9	303 2	307 4

TABLE NO 8c

HIGHEST FLOOD OF 1912

Gage	River Mile	Water Surface elevations, feet above M G L	
		Confined flood	B P -N. M Floodway functioning
River			
Cairo	0	328 3	326 3
Columbus	21 6	320.5	317 5
H. W 176	38 3	314 5	310 5
H. W 112	60 0	306.5	304 9
New Madrid	71 0	300 5	300 4
Floodway			
A_1		dry	319 6
A_2.		dry	320 1
A_3		dry	319 5
B_1		dry	
B_2		dry	318 6
B_3		dry	317 8
B_4		dry	311 1
B_5.		dry	313 0
B_6		dry	314.3
C_1		dry	310 8
C_2		dry	311 3
C_3		dry	311 4
C_4		dry	313 3
D_1		302 0	309.7
D_2 .			309 6
D_3			310 4
E_1		301 8	308 1
E_2		301 4	308 5
E_3		301 4	308 7
F_1		301 4	306.6
G_1		301 4	304 6
G_2		301 6	305 6
G_4			308 9

TABLE NO 8d

HIGHEST FLOOD OF 1913

Gage	River Mile	Water Surface elevations, feet above M G L	
		Confined flood	B P.-N M Floodway functioning
		River	
Cairo	0	329 3	327 6
Columbus	21 6	321 6	318 5
H W 176	38 3	315 5	312 4
H W 172	60 0	307 7	306 4
New Madrid	71 0	301 3	302 2
		Floodway	
A_1		dry	320 1
A_2		dry	320 9
A_3		dry	320 8
B_1		dry	
B_2		dry	319 0
B_3		dry	319 0
C_1		dry	312 5
C_2		dry	313 0
C_3			313 3
D_1		303 2	311 5
D_2			311 5
D_3			312 0
E_1		302 8	309 8
E_2		302 6	310 6
E_3		302 8	310 8
F_1		302 6	308 4
G_1		302 6	306 0
G_2		303 0	307 4
G_3			310 8

TABLE NO 8 e

HIGHEST FLOOD OF 1927

Gage	River Mile	Water Surface elevations, feet above M G L	
		Confined flood	B P -N M *Floodway* functioning
		River	
Cairo	0	328 7	327 1
Columbus	21 6	320 9	318 1
H W 176	38 3	314 8	312 1
H W. 172	60 0	306 8	305 8
New Madrid	71 0	300 9	301 4
		Floodway	
A_1		dry	320 0
A_2		dry	320 5
A_3		dry	320 4
B_1		dry	
B_2..		dry	318 9
B_3		dry	318 8
C_1		dry	312 0
C_2		dry	312 4
C_3		dry	312 6
D_1		302 4	311.2
D_2			311 0
D_3		dry	311 5
E_1		302 2	309 2
E_2		302 0	310.1
E_3.		302 0	310 3
F_1		301 8	318 0
G_1		301 8	305 6
G_2		302 2	306 8
G_3			310 4

TABLE NO 8f

MEAN OF THE HIGHEST FLOODS OF 1882, 1883, 1884, 1912, 1913 and 1927

Gage	River Mile	Water Surface elevations, feet above M G. L	
		Confined flood	B P-N M Floodway functioning
River			
Cairo	0	327 7	325 9
Columbus	21 6	320 1	317 4
H W 176	38 3	113 9	311 3
H W 173	60 0	306 0	304.8
New Madrid	71 0	300 5	300.1
Floodway			
A_1		dry	319 5
A_2		dry	320 1
A_3		dry	320 0
B_1		dry	dry
B_2		dry	318 6
B_3		dry	317 6
B_4		dry	311 2
B_5		dry	313 0
B_6		dry	314.3
C_1		dry	310 5
C_2		dry	311 2
C_3		dry	311 2
C_4		dry	314 0
D_1		302 0	309 5
D_2			309 2
D_3		dry	310.0
E_1		302 0	307 6
E_2		301.4	308.2
E_3		301 4	308 2
F_1		299.8	306 2
G_1		301 4	304 6
G_2		301 8	305 2
G_3		301 4	308 6

APPENDIX C

DATA FOR MODEL CONSTRUCTION

40 The concrete model was reproduced from topographic and hydrographic maps of surveys dating from 1926 to 1931 A short length of river above Cairo was reproduced from charts of the Mississippi and Ohio Rivers published in 1908 This section was not important, serving only as an entrance to the model proper In every case the most recent surveys were used

41 *River channel* —The river channel was reproduced according to the following surveys of the Mississippi River

a *Miles 10 to 2 above Cairo, Ohio River, 4 miles above Cairo, to Cairo* —Charts Nos 16 and 17, Mississippi River, St. Louis to Cairo, Board on Examination and Survey of Mississippi River, 1908 Supplied by the President's Office, Mississippi River Commission

b *Miles 2 above, to 42 below Cairo* —Field Sheets Nos 1 to 7, Survey of the Mississippi River, Cairo to Old River, Mississippi River Commission 1926-27 Supplied by the President's Office, Mississippi River Commission (M R C /2064.)

c. *Miles 42 to 51 below Cairo* —2 sheets, Surveys for Contraction Works, 1930, First Field Area, U S Engineer Office, Memphis, Tenn (Ser 2083—File 190/10, Ser 2045—File 190/8)

d *Miles 51 to 88 below Cairo.*—8 sheets, Compilation Map, Watson Point and Vicinity, from Overbank Surveys 1929-30 and Contraction Works Surveys 1929-31, U S Engineer Office, Memphis, Tenn (Ser 2421—File R C 121)

42 *Overbank between levees* —The topography of the overbank areas between levees, or between levees and hills, was reproduced from the data contained on the above maps except as follows.

a. *Miles 42 to 51 below Cairo.*—Field Sheets Nos. 7 and 8, Survey of Mississippi River, Cairo to Old River, 1926-27 (See 57-b)

43 *Topography of the floodway* —The area lying in the floodway was reproduced from maps and profiles of a special survey of 1931 Elevations of cleared areas are shown by contours to a one-foot interval, while in wooded areas the contour interval is two feet. Cross sectional profiles were drawn of drainage ditches and spoil banks These data are as follows.

a *General topography and lakes.*—Advance photostat, Topographic Survey of the New Madrid Floodway, September, 1931, First Field Area, U S Engineer Office, Memphis, Tennessee

b *Drainage ditches and spoil banks* —Cross-sections, 1931, plotted by First Field Area, U S Engineer Office, Memphis, Tenn.

c *Backside levee borrow pit* —Cross-sections, 1931, plotted by U S Levee Inspector, First Field Area, U S Engineer Office, Memphis, Tennessee

44. *St John Bayou backwater area* —The backwater area at the of St John Bayou and adjacent to the floodway on the lower, western side was reproduced from advance photostats of the alluvial valley maps of the War Department, Corps of Engineers, as follows.

a Missouri Charleston Quadrangle

b Missouri-Kentucky-Tennessee Bayouville Quadrangle

45 *Levees* —Levee locations were obtained from the above river maps. The grades were taken from the following profiles

a *Riverside levee, right bank, from upper limits of model to New Madrid* —Sheets Nos 2 and 3, Upper St Francis District, Levee Profile, Adopted Project 1928, U S Engineer Office, Memphis, Tennessee (Ser 2205—File 1851)

b *Right bank, New Madrid to lower limits of model, New Madrid north to Sikeston Ridge* —Sheets Nos 1 and 2, Lower St Francis District Levee Profile, Adopted Project 1928, U S Engineer Office, Memphis, Tennessee

c *Left bank, Hickman to end of Watson Point Dike* —Reelfoot District, Levee Profile, Adopted Project 1928, U S Engineer Office, Memphis, Tennessee

d *Floodway setback levee* —Profile of Setback Levee, Proposed Birds Point-New Madrid Floodway, dated December 4, 1828, U S Engineer Office, Memphis, Tenn (Ser 1477)

APPENDIX D

HYDRAULIC DATA

46 The hydraulic data on which the operation of the model was based included special studies of the floodway and records of the Mississippi River Commission Computations necessary for the model study were prepared by the U S Waterways Experiment Station

47 *Floodway studies* —Previous to construction, studies were made of the hydraulics of the floodway, and are here listed

a *Plan* —The plan was outlined in a "Report on Proposed Birds Point-New Madrid Floodway", letter from the District Engineer, U S Engineer Office, Memphis, Tennessee, to the Chief of Engineers, U S Army (through the President, Mississippi River Commission, St Louis Mo) dated December 4, 1928, (File No 37/7)

b *Original hydraulic computations* —Hydraulic Study of Proposed Birds Point-New Madrid Floodway, U S Engineer Office, Memphis, Tenn , dated November 22, 1928

c *Recent computations* —Letter from the District Engineer, Memphis, Tenn to O M Page, Agricultural Engineer, U S. Department of Agricultural (through the Area Engineer, First Field Area, Cairo, Ill), dated Oct 21, 1931

d *Hydrographs, etc* —Mississippi River, Hydrographs and Supporting Data for Various Floods at Cairo, Ill , U S Engineer Office, Memphis, Tennessee, dated April and May, 1931 (Ser Nos 2254 and 2233)

48 *Flow in main river* —Flow in the model river was checked against flow during 1929 in the Mississippi River, there having occurred during that year a major flood which was held confined by the levee system, and for which ample gage records and discharge measurements are available

a. *Discharges.*—Discharge-gage height curve was plotted by the U. S. Waterways Experiment Station from Results of Discharge Observations, Mississippi River at Hickman, Ky., U. S. Engineer Office, Memphis, Tennessee, (M. R. C. file 3015/C. A., Part III).

b. *High water profile, 1929 flood.*—Upper St. Francis District Levee Profile, Adopted Project 1928, U. S. Engineer Office, Memphis, Tennessee, (Ser. 2205—file 185/1).

c. *Gage relations between Cairo, Columbus, and New Madrid.*—Relations of highest stages between Cairo, Columbus, and New Madrid, 1850 to 1929, and relations of daily stages during the 1929 flood were plotted by the U. S. Waterways Experiment Station from published gage records of the Mississippi River Commission.

APPENDIX E

DATA FOR MODEL TO DETERMINE EROSIVE PROPERTIES OF UPPER FUSE PLUG LEVEE

49. The model to determine the erosive properties of the upper fuse plug was constructed of soil taken from borings in the existing levee. It was built to width and depth scales of 1/20 and a length scale of 1/4800.

50. *Soil.*—Soil samples were taken from borings in the upper fuse plug section by the First Field Area, U. S. Engineer Office, Memphis, Tennessee.

51. *Charts.*—The composition of the fuse plug was shown by the following: Profile and Borings of the Upper Fuse Plug Section, Birds Point-New Madrid Floodway, Levee Mile Post 33/20 to 44/20, U. S. Engineer Office, Memphis, Tenn., 1931.

52. *Crevasse Studies.*—A general investigation was made of crevasses which have occurred on the Mississippi River. This reasearch included an examination of both written and photographic records of the Mississippi River Commission and the Engineer Offices under its jurisdiction. In addition, much information was obtained verbally or by personal inspection. Due to the voluminous mass of data, only the information directly pertinent is listed here.

a. *Crevasses in Mississippi River Levees, 1770 to 1874, and 1882 to 1930.*—Annex No. 5, Basic Data Mississippi River, compiled by First Lieut. Herbert D. Vogel, Corps of Engineers (43783—H. Doc. 798, 71-3, Vol. 1-5), pages 125-137, Table No. 24. Table of crevasses on the Mississippi River below Cairo, Ill.

b. *Dorena Crevasse.*—Map, Dorena Crevasse 1927, with preceding and succeeding bank lines, U. S. Engineer Office, Memphis, Tenn. (Ser. 2498). Soil survey, Dorena Crevasse, Mississippi County, Missouri, O. M. Page, Agricultural Engineer, U. S. Department of Agriculture (to accompany letter to the District Engineer, U. S. Engineer Office, Memphis, Tennessee.)

WAR DEPARTMENT

CORPS OF ENGINEERS, U.S. ARMY

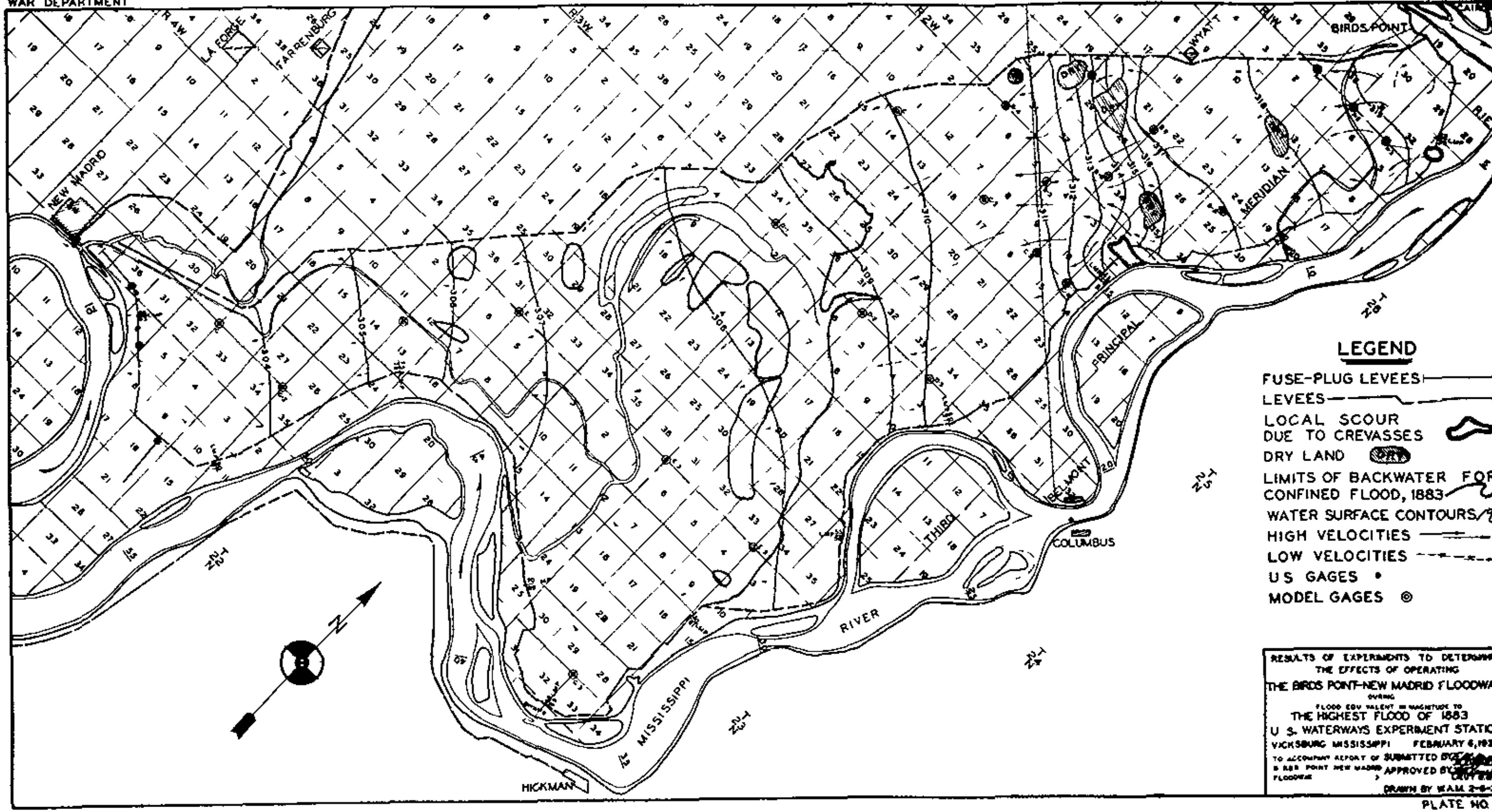


PLATE NO. 1

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY

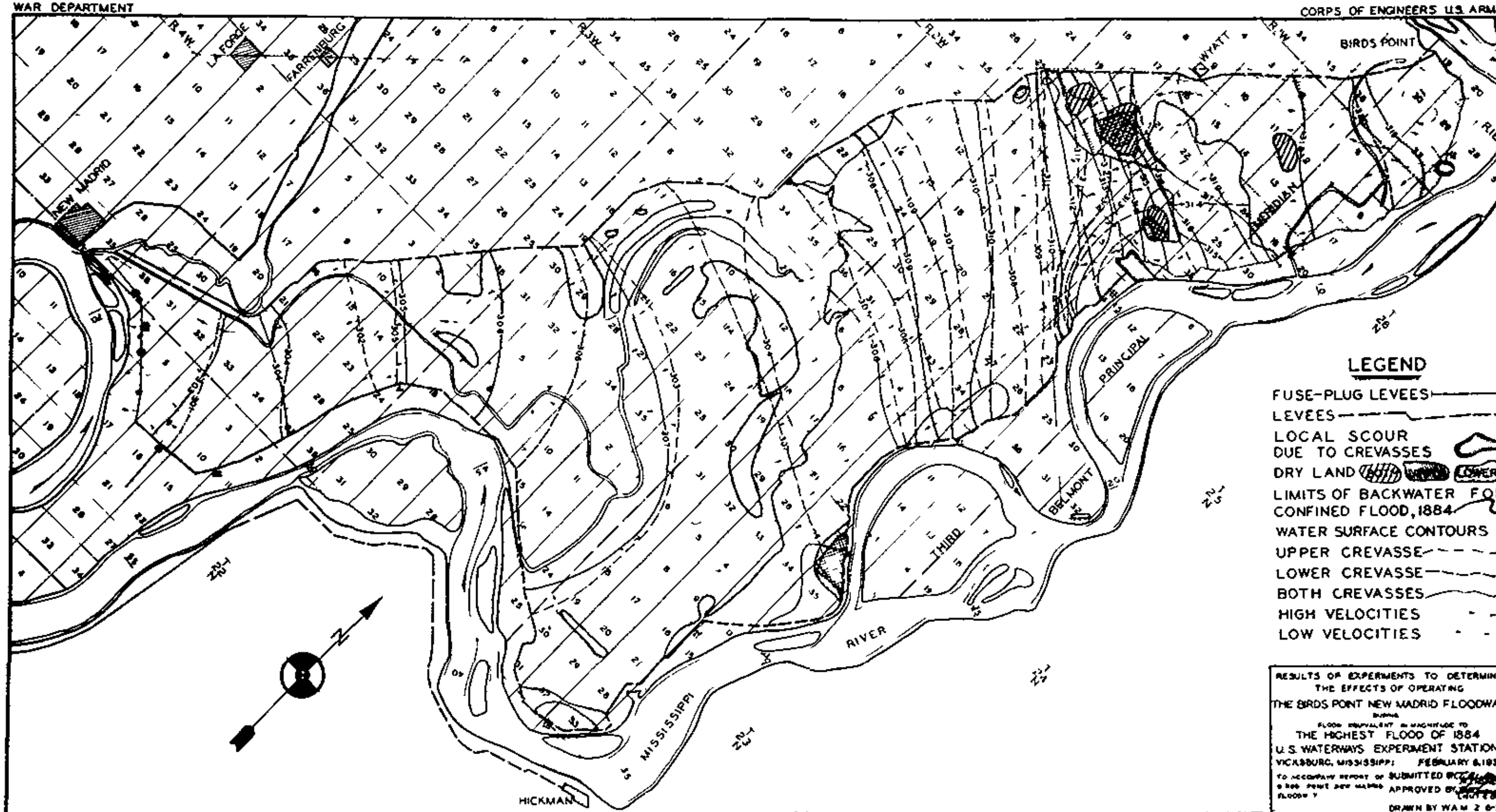


PLATE NO 2

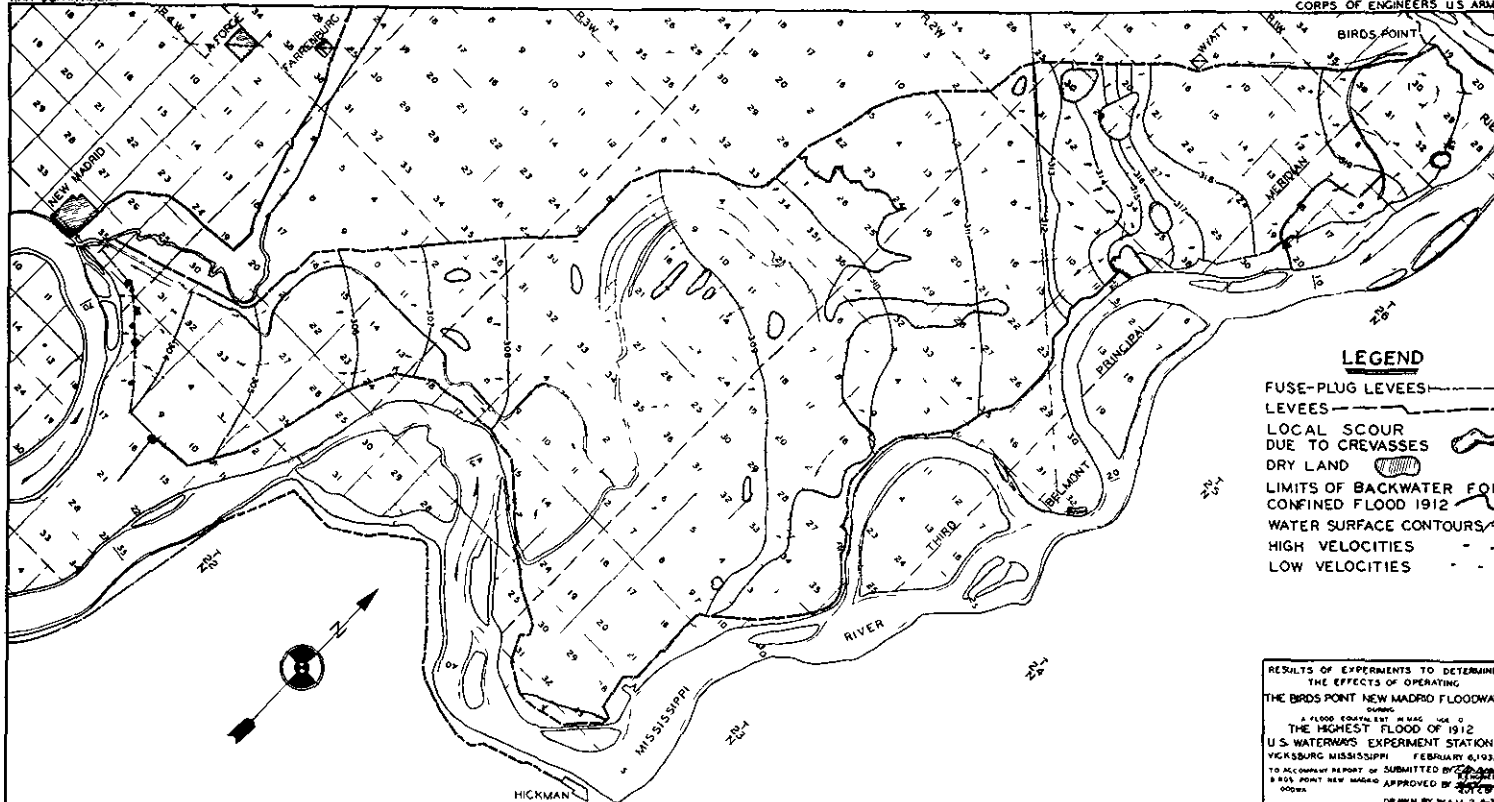
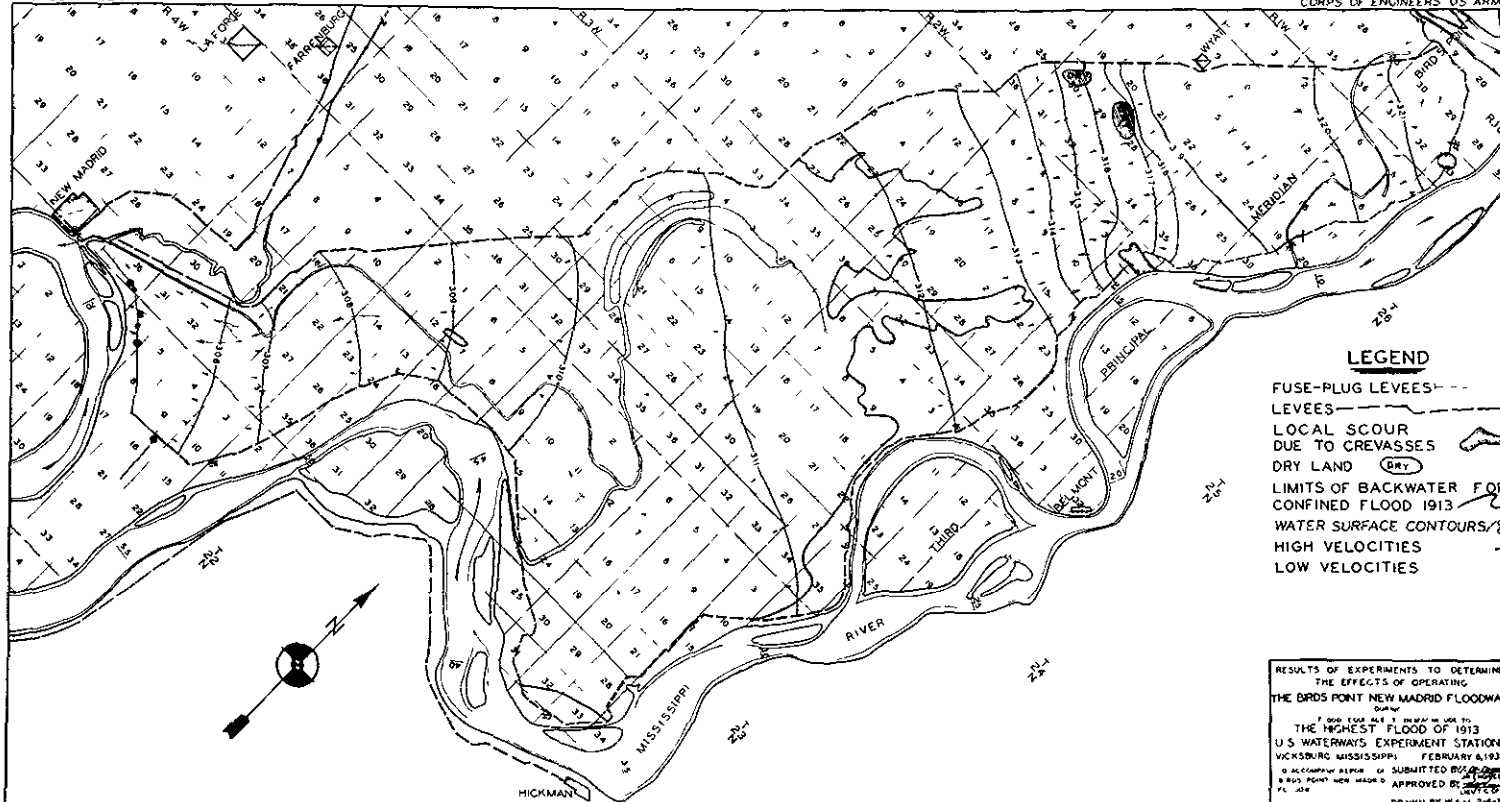

NEW MADRID
LA FORGE
FARRENBURG
WYATT
BIRDS POINT
R.4W.
R.3W.
R.2W.
R.1W.
R.1E.
MERIDIAN
PRINCIPAL
BELMONT
THIRD
MISSISSIPPI
RIVER
HICKMAN
LEGEND
FUSE-PLUG LEVEES
LEVEES
LOCAL SCOUR DUE TO CREVASSES
DRY LAND
LIMITS OF BACKWATER FOR CONFINED FLOOD 1912
WATER SURFACE CONTOURS
HIGH VELOCITIES
LOW VELOCITIES
RESULTS OF EXPERIMENTS TO DETERMINE
THE EFFECTS OF OPERATING
THE BIRDS POINT NEW MADRID FLOODWAY
THE HIGHEST FLOOD OF 1912
U S. WATERWAYS EXPERIMENT STATION
VICKSBURG MISSISSIPPI FEBRUARY 6,1932
SUBMITTED BY
APPROVED BY
DRAWN BY W.A.M. 2-6-32

PLATE NO 3

WAR DEPARTMENT

CORPS OF ENGINEERS US ARMY



RESULTS OF EXPERIMENTS TO DETERMINE THE EFFECTS OF OPERATING
THE BIRDS POINT NEW MADRID FLOODWAY
THE HIGHEST FLOOD OF 1913
U S WATERWAYS EXPERIMENT STATION
VICKSBURG MISSISSIPPI FEBRUARY 6,1932
SUBMITTED BY
APPROVED BY
DRAWN BY W.A.M. 2-6-32

PLATE NO 4

WAR DEPARTMENT

CORPS OF ENGINEERS U.S.ARMY

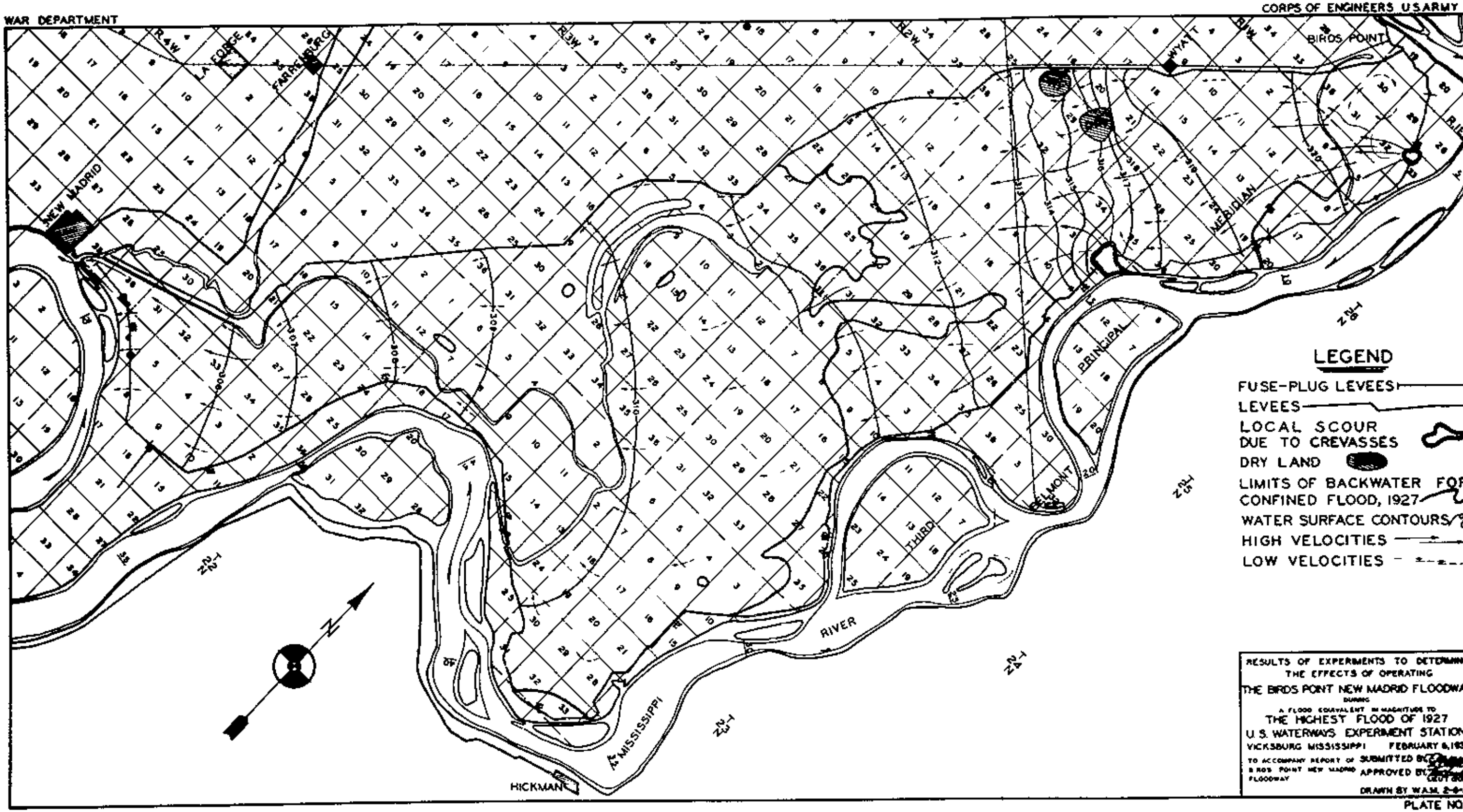


PLATE NO 5.

WAR DEPARTMENT

CORPS OF ENGINEERS U.S. ARMY

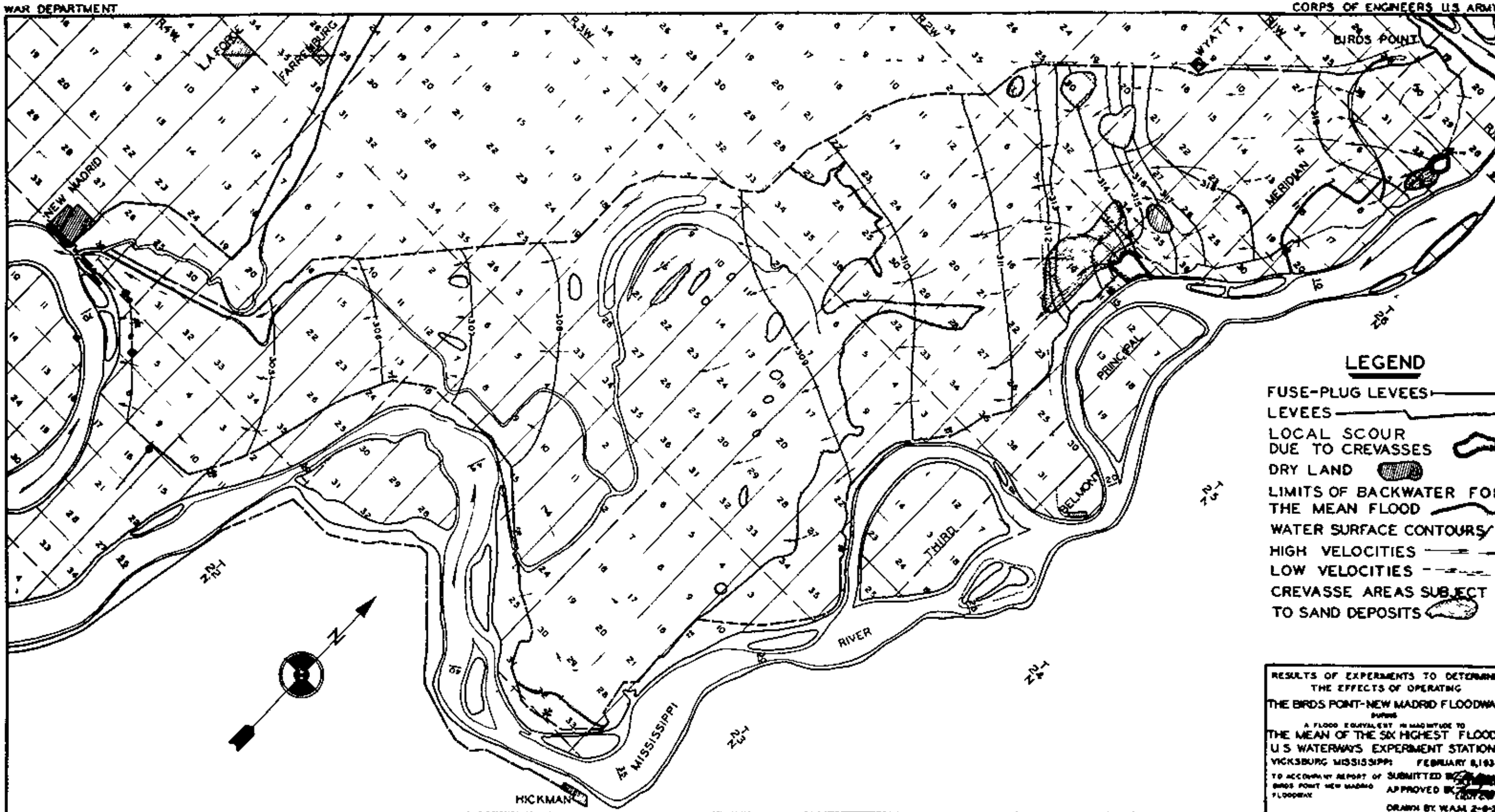


PLATE NO 6